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ABSTRACT

This Extension Service publication from Oregon State University explains the Long Range Navigation or Loran system and what to look for in a Loran-C receiver. There are two Loran systems, Loran-A and Loran-C, the latter of which will be completed by 1980. The Loran-C system operates at 100 kiloHertz and a ship at sea can be navigated by analyzing time difference readings of a master and several secondary broadcast stations. In order to help seamen and boaters select a Loran-C receiver to fit their needs, the function of the Loran-C system and what a receiver can do is explained. Aspects of the Loran-C system described are: (1) Multiple-pulse transmissions; (2) Phase coding; (3) Envelopes and cycles; (4) Sky waves; and (5) Manual aquisition and automatic aquisition. Discussions included to assist in receiver selection are: (1) basic characteristics of all receivers; (2) conversion of Loran-A receiver to Loran-C; (3) importance of receiver installation; and (4) practical tips on receiver selection. A consumer checklist for Loran-C receivers and a glossary of terms is also included. (MR)

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What you should know about Loran-C receivers

by Daniel A. Panshin
Extension Oceanographer
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Are you ready for Loran-C? What kind of Loran-C receiver will you use? What should you know about Loran-C receivers before deciding? Can you convert your Loran-A receiver? Selection of a Loran-C receiver best suited to your navigational needs is an important decision. It is time to start thinking about that decision.

Loran-C covers part of the U.S. waters now, and by 1980 it will be available all around the United States except northern Alaska. Loran-C will cover much more of the ocean off the U.S. than Loran-A, with no gaps, and it will also include the Great Lakes and much of the continental United States. Loran-C is accurate, dependable, and long-range. It will replace the present Loran-A system, which will be turned off after two years of overlapping Loran-C service. (For information on the schedule and on the extent of Loran-C coverage in your area, check with your local Sea Grant advisory agent or your Coast Guard District office, or write to Loran-C Information, U.S. Coast Guard, Washington, D.C. 20590.)

This bulletin assumes you are already familiar with Loran-A. If you are not, you may want to do some background reading. See "For more information," page 8, for suggestions.

By 1980, Loran-C will cover coastal waters all around the United States (except the North Slope of Alaska), the Great Lakes, and most of the contiguous 48 states as well. Loran-C will serve a much larger area than Loran-A, with higher accuracy and no gaps in marine coverage. Loran-C is also available in the Hawaiian Islands and in portions of the western Pacific, the North Atlantic, and the Mediterranean.

Another title in the series
Marine electronics

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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What is Loran?

Loran stands for *long range navigation*. It is an electronic system that helps vessels to determine their position at sea by using shore-based radio transmitters and onboard receivers. Loran works in any kind of weather, 24 hours a day.

What are the basic differences between Loran-A and Loran-C?

Loran-A was developed during World War II. Loran-C is an improved version dating back to the late 1950's. Loran-C uses a lower frequency, 100 kHz (kHz = kiloHertz = kilocycles/second = thousand cycles per second), compared with 1850 to 1950 kHz for Loran-A. The lower frequency gives Loran-C a longer range and allows for greater accuracy. Loran-C uses advanced electronic technology, including the more accurate *cycle-matching* method, rather than the *envelope-matching* Loran-A method. (To help you understand technical terms, those terms that are *italicized* in the text are defined in the glossary on page 8. In addition, most of the terms used here are explained in following sections.)

Other technical improvements of Loran-C include multiple-pulse transmissions, *phase coding*, freedom from *sky-wave* contamination, and the ability to use more sophisticated receivers. As a result, Loran-C can tell you where you are within one-tenth to one-half nautical mile (*geodetic, or absolute, accuracy*) and help you return to the same spot, time after time (*repeatable accuracy*), within 15 to 90 meters (50 to 300 feet), depending on your location within the Loran coverage area.

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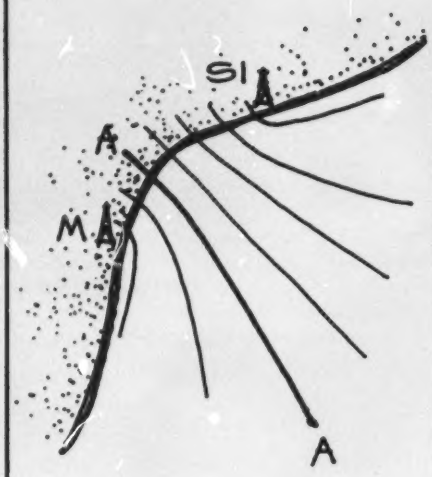
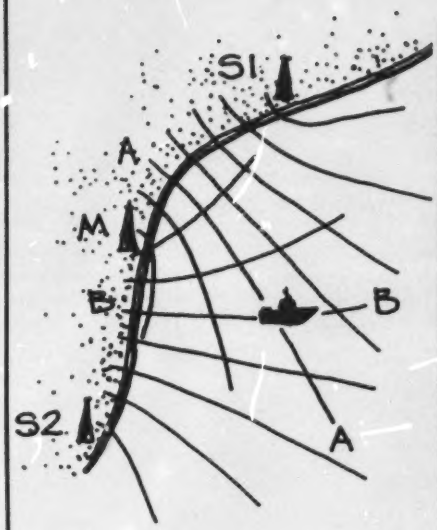


What does a Loran receiver do?

A Loran receiver measures the difference in time of arrival of two different radio signals, one from a master transmitting station, the other from a secondary transmitting station. The time difference is very small and is read out in microseconds (millionths of a second), or "mikes" in common marine language. A Loran-A reading contains four digits, such as 1526, whereas a Loran-C reading contains five digits and usually includes tenths as well, such as 13970.6.

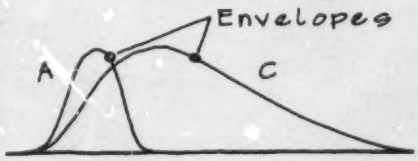
Because Loran signals travel at a known speed, a time-difference reading allows you to plot your position as a line of position on a chart. If, for instance, you tune your receiver to master signal M and secondary signal S1 and obtain a time-difference reading of A, you know that you are somewhere on line A, which is printed on the chart (as suggested by the drawing above).



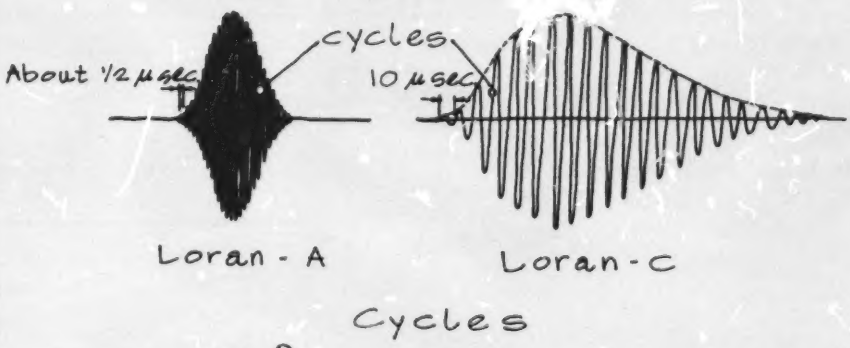
To fix your position, more information is needed, such as a visual bearing, radar range, depth sounding, or second Loran reading. In many locations, two good Loran-A readings are available; in other locations, as on the West Coast, for example, it is common to fix your position with one Loran-A reading plus a sounding. With Loran-C, however, two good Loran readings will be available in all parts of the coverage area. So assume that you take a second Loran reading, this time from master station M and secondary station S2, obtaining a time difference of B. You have thus located yourself at the intersection of lines A and B (as illustrated above).

In some ways, Loran-A and Loran-C receivers are similar; in others, they are quite different.

Envelopes and cycles. Both Loran-A and Loran-C receivers measure time differences between master and secondary signals, but they work in different ways; Loran-C signals are different from Loran-A signals. If you could look at both a Loran-A and a Loran-C signal on the same oscilloscope, they would look like this:

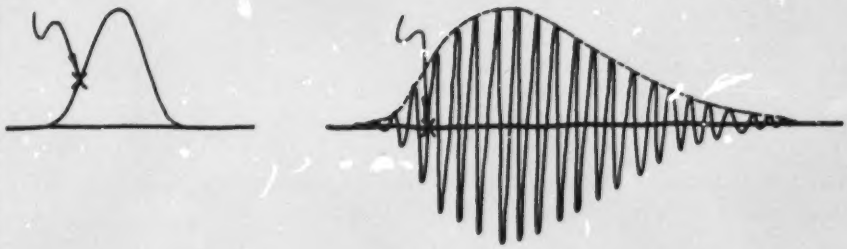


In this case, the oscilloscope presents the pulse envelopes, which are an outline of the peaks of the actual radio-frequency cycles that have been transmitted. By contrast, the cycles that make up the pulse envelopes look like those shown below.



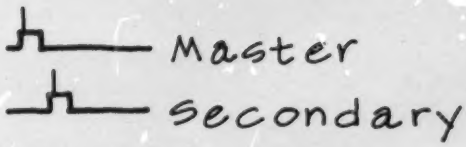
With Loran-A, only the envelopes are used for making time-difference measurements. This technique is called *envelope matching*. In the case of Loran-C, however, the signal is broadcast so that both envelopes and cycles are used to make time-difference measurements. To obtain the full accuracy of Loran-C, the receiver makes a coarse match on the envelopes and a fine match on the cycles. This technique is called *cycle matching*. Loran-A signals have cycles, too, as shown on the bottom of page 2, but they are too closely spaced and susceptible to interference to use in making measurements.

Loran time differences are measured by matching master and secondary signals at the points illustrated (top right):



A - envelope C - cycles

Multiple-pulse transmissions. Another difference between Loran-A and Loran-C is the number of pulses each transmits. When operating with Loran-A, you select a rate that covers your area, such as 1H5. This selection tunes in one master transmitter and one secondary transmitter, each of which broadcasts just one pulse. With your receiver controls set on Function 1, Loran-A signals look like this on the oscilloscope:



Loran - A, Function 1

When operating with Loran-C, you also select a rate that covers your area, such as 9940. This selects one master transmitter and from a minimum of two to as many as five secondary transmitters. The master transmitter broadcasts a **series of nine** pulses, and each secondary transmitter broadcasts a **series of eight** pulses. If we once again set our receiver to Function 1 and look at 9940 (the U.S. West Coast chain), for instance, there are three secondaries, and its appearance on an oscilloscope might look like the drawing at the right :

Loran - C, Function 1

Phase coding. Each of the Loran-C pulses is also phase-coded. A pulse can have positive phase or negative phase, which indicates whether the cycles start positively (up) or negatively (down), as shown in the drawings at the lower right. The series of eight (secondary) or nine (master) pulses is transmitted in a sequence of positive and negative pulses, such as +−+−+ +−−. The sequence or code for master-station transmissions is different from that of secondary-station transmissions.

Phase coding allows automatic Loran-C receivers to distinguish between master and secondary transmissions, and it helps the receivers to operate when the Loran signals are weak compared to the background noise. By contrast, Loran-A signals are not phase-coded.

Positive (+) Phase Code Negative (−) Phase Code

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Sky waves. Yet another difference between Loran-A and Loran-C is the effect of sky waves—that is, signals that bounce off the ionosphere instead of traveling directly from transmitter to receiver. Sky waves are especially strong at night (above).

Sky waves always arrive later than ground waves—that is, signals that have traveled a direct path from transmitter to receiver. The sky-wave signal can be much stronger than the ground-wave signal, a situation that can make envelope time-difference measurements confusing or difficult.

With Loran-A, sky waves are a problem, just as they can be with Loran-C manual receivers. Since Loran-C sky waves can arrive before the peak of the ground wave, the Loran-C ground-wave envelope will be distorted under this condition, and the apparent position of the peak of the envelope will shift. The result is that under this condition Loran-C envelope matching on a manual receiver will be erroneous. With Loran-C automatic receivers, sky waves pose no problem as long as the ground-wave signal is strong enough to use: The standard point for matching Loran-C signals with automatic receivers is 30 microseconds after the beginning of the pulse, and sky waves do not arrive before this point.

Manual acquisition and automatic acquisition. Manual-acquisition Loran-C receivers are like most Loran-A receivers: You must match pulse envelopes visually as your first step. To be able to match envelopes on an oscilloscope, you must be able to see the envelopes, or signals, above the background radio noise, or "grass." The signal levels need to be somewhat higher than the noise level before you can match them.

If, for instance, a signal is exactly twice as high as the noise, this situation is described as having a *signal-to-noise ratio*, or *SNR*, of 2:1. Once you have acquired the signals manually, you may then track them manually or automatically, depending on the type of receiver you have. A point to note, by the way, is that there is appreciably more background noise at 100 kHz, the Loran-C frequency, than there is at Loran-A frequencies.

Automatic-acquisition Loran-C receivers match signals electronically. By fully using the information available through cycle matching, multiple-pulse transmissions, and phase coding, automatic receivers can match signals that would be invisible to the eye on an oscilloscope because they are not strong enough to be seen above the noise.

Full Loran-C coverage depends on the ability of receivers to acquire and track signals under conditions where the noise is as much as three times higher than the signal, that is, where the SNR is 1:3. (Of course, in much of the Loran-C coverage area, the signal is stronger than this level.) All receivers that can acquire signals automatically also track signals automatically.

Other differences. There are a number of other differences among Loran-C receivers, whether manual or automatic. Some of them are:

1. *the number of chains the receiver can process* (some receivers are intended for regional use and can only process one chain; if you wish to operate in another area with this kind of receiver, you must have the factory or a dealer change your receiver from one chain to another);
2. *the number of secondary stations simultaneously tracked* (one, two, or more);
3. *the number of time differences displayed* (if the receiver tracks only one secondary, it will only display one time difference; if it tracks two or more, however, it will have either one display that shows two time differences alternately, or two separate displays); and
4. *the type of signal matching* (cycle or envelope).

What are some basic characteristics common to all receivers?

First, a note of caution. As with all marine equipment, let the buyer beware. Performance data, or receiver specifications, that are presently available represent information that manufacturers provide. Because there are no standard testing procedures, no common basis exists for making numerical comparisons. For this reason, this bulletin does not generally present numbers.

You should be aware of these basic characteristics as you make your receiver decision:

Receiver band width. At the heart of a Loran set is a special-purpose radio receiver. Since the Loran-C signal falls within the frequency band of 90 to 110 kHz, peaking at 100 kHz, the receiver must cover this frequency range. Because of different electronic approaches to processing the Loran-C signal, some receivers are relatively broadband (that is, they receive signals well outside 90 to 110 kHz), whereas others are quite narrow in the range of frequencies they receive.

There are trade-offs with both approaches. If the receiver is broadband, it may also receive unwanted signals; you will then need to remove them (by using *notch filters*, which are discussed in the next paragraph). If the receiver is too narrow-band, the Loran-C signal is distorted, resulting in possible errors in time-difference readout.

Notch filters is the name given electronic filters in the receiver that reduce the effects of interfering signals. Interfering signals are human in origin; they can be from radio broadcast stations or from special stations such as Decca. (The Coast Guard has assembled a list of known interfering signals by region; to obtain a copy, write to Loran-C Information, U.S. Coast Guard, Washington, DC 20590, specifying the region in which you are interested, and ask for a copy of the "Loran-C Interference List.") To obtain optimum Loran-C performance, it is important that your receiver have the proper number of notch filters, usually two to four, and that they be set properly.

Sensitivity is a measure of the minimum signal level at which a receiver can function. The more sensitive the receiver, the greater the distance it will work from Loran transmitters, so long as the background noise is not excessive (that is, so long as the signal-to-noise limit for the receiver is not exceeded).

Dynamic range indicates the ability of a receiver to process both weak and strong signals. As stated above, sensitivity provides a measure of how far from Loran transmitters a receiver can function under low-noise conditions; dynamic range, in conjunction with sensitivity, provides a measure of how close to Loran transmitters a receiver can function.

Differential gain indicates the difference in strength between a master signal and a secondary signal that the receiver can handle. A high differential gain is desirable and means that the receiver can successfully compare a very strong signal with a very weak signal, an especially important capability if you will be operating close to a Loran-C transmitting station.

Power consumption is an important consideration, especially for small boats that have limited electrical power. Receivers vary widely in their power requirements, drawing from 10 to 100 watts. Most receivers can operate on either AC or DC, although AC capability is often an optional feature.

Display. Most Loran-C sets show time-difference readings on a lighted display. If the receiver tracks two secondaries, the time differences can be shown alternately on one display, or they can be shown simultaneously on two separate displays.

Readout resolution—that is, whether the display shows time differences in whole microseconds, tenths, or hundredths—is important. Regardless of the features of your receiver, you need a display that shows time increments at least as small as **tenths of a microsecond** if you are to obtain full Loran-C accuracy.

There are other display features you will probably want to check into. How frequently does it update the time differences? Is the display easy to read? Is it legible in bright sunlight? Can you dim the display at night?

You should also consider design features such as dimensions, weight, convenience of controls, mounting, and moisture resistance as you select your Loran-C set.

Are there other features you should consider?

Definitely, yes! Some of the other features that may be available are important to have; others are nice to have:

Number of secondaries tracked. All Loran receivers track and display time-difference readings between the master and one or two secondaries. If the receiver tracks or matches just one secondary, then it is necessary to go through the acquisition and matching process again to obtain a second Loran time difference, and thus determine your position from Loran.

If the receiver tracks two secondaries simultaneously, you have enough information to determine your position from Loran anytime without delay. A receiver's ability to track more than two secondaries provides flexibility immediately to display time differences from another secondary of the same chain, a feature which may be desirable on a long transit.

Cycle-step switch. Since an automatic receiver can match the wrong cycle under certain conditions, time-difference readings in such a case will be in error by a multiple of 10 microseconds (1 Loran-C cycle is 10 microseconds long). A cycle-step switch allows the operator manually to increase or decrease the time-difference readings by 10-microsecond intervals, thereby helping the receiver to correct an error.

A memory button allows you to freeze an important reading until you have a chance to write it down. When you engage the memory button, the receiver continues to track internally, and the time-difference readings then update as soon as you release the memory button.

Alarm indicators on automatic receivers inform you of various conditions when the time-difference readings are not usable:

- **Blink alarm** indicates that the master or one of the secondary stations is not transmitting the correct signal.
- **Lost-signal alarm** indicates that the signal is too weak for the receiver to function properly.
- **Cycle alarm** indicates the receiver is tracking the incorrect cycle on one or more signals. The cycle alarm may also come on when the receiver is in fact tracking the correct cycle but has not passed all internal tests necessary to assure that it is tracking the correct cycle.

Can you convert your Loran-A receiver to Loran-C?

It is possible to convert some Loran-A receivers to Loran-C. There are also Loran-A/C combination receivers that can operate on both Loran-A and Loran-C signals. Convertible and combination receivers are basically Loran-A receivers. Whether or not one of these receivers will work for you is something only you can decide.

In part, the answer depends on your needs for accuracy and the strengths of the Loran-C signals in your area. Convertible and combination receivers require very strong Loran-C signals from **three** transmitting stations (if you want two readings), and they do not offer the accuracy of a fully automatic Loran-C receiver.

Is the installation of your receiver important?

Proper installation of your Loran-C receiver is critical to good performance, much more so than with Loran-A. Proper installation requires time and skill, and a competent, factory-trained dealer should do it. Antenna location, grounding, interference suppression, and receiver placement are all important:

Antenna. Make sure you use a correct antenna and antenna coupler for your receiver. Mount the antenna as high as possible and as far away as possible (at least 3 meters or 10 feet) from all metal objects, stays, and other antennas. Do not connect any other equipment to your Loran-C antenna.

Grounding. Connect both the antenna coupler and the receiver to a good ground. At lower operating frequencies, such as Loran-C at 100 kHz, the ground becomes more critical.

Interference suppression. Electrical and electronic interference, or noise, can come from many sources, both aboard the vessel as well as from the surrounding environment. Onboard noise comes from everything that generates or uses electricity; it is a much more severe problem at the 100-kHz Loran-C frequency than at higher frequencies, and you must suppress it if you are to have good Loran-C results.

Special culprits include alternators and generators, ignition system, electric motors, fluorescent lights, radars, television sets, and other electronic equipment. Interference suppression may require installation of filters, shields, grounds, and capacitors plus considerable ingenuity and persistence. Make sure to accomplish the interference suppression with your engine running—along with all the equipment you would normally operate at sea.

Receiver placement. Protect your receiver from excessive heat, dampness, salt spray, and vibration. Do not mount it in direct sunlight or within 1 meter (3 feet) of your magnetic compass. Provide adequate ventilation.

A half-dozen practical tips

1. **Buy the type of Loran-C set that matches your needs.** Do not buy more than you need; do not buy less than you need. Buy carefully. It is an important decision. Consult table 1, summarizing types of receivers, and the consumer checklist, page 7.
2. **How automatic is automatic?** All you have to do with some sets that are called automatic is turn them on. With others, you have to perform one or more of these additional functions: Select chain, set notch filters, select secondary stations. Understand what you are getting, what the set will do for you, and what operations you have to do.
3. **If at all possible, try out the set you are considering on a vessel of the same type as yours, in your general area, before you buy.** At a minimum, operate the set in a dealer's showroom on a live antenna using real Loran-C signals, not on a test signal. Try out the set during nighttime as well as daytime. How easy is the set for you to operate? What is its reputation in the fleet? How long does it take the set to acquire Loran-C signals, to lock on to the correct cycles, and start tracking?
4. **Buy from a reputable dealer.** Make sure that the dealer is technically competent. Make sure that the dealer will install and service your set. Make sure that the dealer has adequate factory support.
5. **Check the warranty carefully.** A good warranty is important; Loran-C repairs can be expensive. Watch out for unusually short warranty periods.
6. **Do not depend exclusively on Loran-C,** regardless of how fine a receiver you buy. The prudent navigator uses all the navigational information that is available. Loran-C, just like all other marine electronics equipment, can break down and give erroneous readings.

Table 1.—*Comparison of types of Loran-C receivers*

	Manual acquisition		Automatic acquisition	
	Manual tracking	*Automatic tracking*	*Automatic tracking*	*Sophisticated*
Operator actions required	Turn on Select chain Set notch filters Acquire master Select secondary Match envelopes Match cycles (if available) Set gain controls	Turn on Select chain Set notch filters Acquire master Select secondary Match envelopes Match cycles Set gain controls	Turn on Select chain (unless preset) Set notch filters Select secondaries (unless preset)	Turn on Select chain Set notch filters Select secondaries
Advantages	Lowest cost Can convert from A or use A/C combination (some models)	Moderate cost Continuous tracking (one secondary) High accuracy Can convert from A or use A/C combination (some models)	High accuracy Long range Full Loran-C coverage Simple operation	High accuracy Long range Full Loran-C coverage Simple operation Extra features (latitude-longitude conversion, etc.)
Disadvantages	Lowest accuracy Shortest range (needs high SNR) Not usable in some areas Tracks one secondary at a time High degree of operator involvement	Needs high SNR for acquisition Tracks one secondary at a time Medium degree of operator involvement	Expensive Complex electronics (Some sets more automatic than others; features vary)	Very expensive Complex electronics Possible unrecognized errors in computations associated with extra features

CONSUMER CHECKLIST—LORAN-C RECEIVERS

Brand/Model Store/Salesperson				My needs
Retail price *Includes antenna and coupler?* (Yes/No)				
Includes installation? (Yes/No)				
Design *Dimensions* (H×W×D)				
Weight				
Mounting: Convenience, Space required (H×W×D)				
Controls: Convenience				
Power required *AC, DC (volts?), watts*				
Basic features *Matching (envelope, cycle)*				
Acquisition (manual, auto)				
Tracking (manual, auto)				
Number of pulses tracked?				
Number of notch filters?				
Chain selection (preset, selectable)				
Other features *Number of secondaries tracked?*				
Cycle step switch? (Yes/No)				
Memory button? (Yes/No)				
Alarms: *Blink? (Yes/No)*				
Lost signal? (Yes/No)				
Cycle? (Yes/No)				
Reputation *Manufacturer*				
Model				
Dealer *Reputation*				
Install?				
Service?				
Factory support				
Warranty *Length*				
Coverage				
Personal *Impression*				
Have you operated set? (Yes/No)				
Other comments				

SG 50, *What you should know about Loran-C receivers*, Oregon State University Extension Service, Sea Grant Marine Advisory Program, Corvallis (5-78)

Accessories

There is a wide range of equipment available other than the basic Loran-C receiver:

A remote readout is a separate display unit that presents the same time-difference information as the receiver at a different location on your vessel. Remote readouts are valuable if you need Loran readings in a second location, or if you wish to locate your receiver in a more protected part of your vessel and use a remote readout in your navigation area.

Track plotters take their signals from a Loran-C receiver and provide an inked trace on a chart of the vessel's location. Some track plotters work from a relative reference system, where one set of Loran-C lines is vertical on the plotter and the other is horizontal. Others work from a conventional reference system, where north-south is vertical, east-west is horizontal, and you can select any chart scale you need. Track plotters present a continuous record of your vessel's movements, a more complete and convenient recording of the same kind of information that many mariners record in log books.

Track plotters take particular advantage of Loran-C's *repeatable accuracy*, and can be especially valuable to commercial operators such as crabbers, shrimpers, lobstermen, and draggers, who need to return as accurately as possible to a previous location. Satisfactory track-plotter operation depends on accurate location of your initial position.

Some receivers use **microprocessors**—special-purpose minicomputers—to aid in processing Loran-C signals. Microprocessors can also allow computation of latitude and longitude through the use of **coordinate converters.** While such information may be desirable, you may get less rather than more: Microprocessor computation of latitude and longitude at this time does not take into account Loran-C transmission anomalies and may include other minor computational errors as well. Unless you determine and apply a local correction, the resultant latitudes and longitudes will be less accurate than if you plotted your Loran-C position on a chart and read off latitude and longitude.

Microprocessors can also compute Loran-C signal strength, receiver tracking status, speed, distance, range, and courses to steer. (Depending on how the calculations are made, the above cautions also apply to microprocessor computations of speed, distance, range, and course.) A development to watch for in the near future will be the introduction of accessories that use microprocessor-computed steering information to drive autopilots.

Glossary of terms

Absolute accuracy: See *geodetic accuracy.*

Cycle matching: A technique that matches the radio-frequency cycles that make up the pulse envelopes. Cycle matching is used to obtain full Loran-C ranges and accuracies.

Envelope matching: A technique that matches the pulse envelopes that are an outline of the radio-frequency cycles. Envelope matching is used in Loran-A receivers and for coarse matching in Loran-C receivers.

Geodetic accuracy: A measure of your ability to determine true geographic position—namely, latitude and longitude—from a navigation system such as Loran; it is also known as *absolute accuracy.*

Ground wave: A signal that travels directly from transmitter to receiver.

Notch filters: Filters in the receiver that may be tuned so as to reduce the effects of interfering signals.

Phase coding: The predetermined pattern of positive and negative phases for each pulse in master and secondary Loran-C signals. Phase coding reduces sky-wave interference and helps Loran-C receivers to distinguish between master and secondary signals.

Repeatable accuracy: A measure of your ability, through using a navigation system such as Loran, to return to a position where you have been before.

Signal-to-noise ratio, or *SNR:* The ratio of the Loran-C signal level to the level of background noise. Loran-C coverage charts show the area within which the SNR is 1:3 or stronger.

Sky wave: a signal that reflects off the ionosphere, rather than traveling a direct path from transmitter to receiver.

For more information

On the principles of Loran: Consult any good basic text on navigation. Two of the best are *American Practical Navigator* ("Bowditch"; Washington: U.S. Government Printing Office, 1962 or later edition) and G. D. Dunlap and H. H. Shufeldt, *Dutton's Navigation and Piloting* (Annapolis: U.S. Naval Institute, 1969 or later edition).

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